Annales Societatis Geologorum Poloniae (2012), vol. 82: 105–120.

ICHNOLOGY OF CZARNA SHALE FORMATION (CAMBRIAN, HOLY CROSS MOUNTAINS, POLAND)

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Stachacz, M., 2012. Ichnology of Czarna Shale Formation (Cambrian, Holy Cross Mountains, Poland). *Annales Societatis Geologorum Poloniae*, 82: 105–120.

Abstract: Ten ichnogenera and seven ichnospecies are described from the Czarna Shale Formation, possibly representing the Terreneuvian and Cambrian Series 2 of the Holy Cross Mountains. Moreover, five other ichnotaxa are described in open nomenclature. *Phycodes circinatus*, ?*Taenidium* isp., *Trichichnus linearis* and ?*Dictyodora* isp. are described from the Cambrian of the Holy Cross Mountains for the first time. The stratigraphic ranges of *Trichichnus linearis* and *Phycodes circinatus* are extended. The trace fossil assemblage and associated, sedimentological features point to deposition in the upper and lower offshore. Periodic, anoxic events may have occurred on the sea bed.

Key words: Cambrian, Terreneuvian, Cambrian Series 2, trace fossils, Holy Cross Mountains, Czarna Shale Formation.

Manuscript received 29 April 2012, accepted 4 September 2012

INTRODUCTION

The Holy Cross Mountains are subdivided into the Łysogóry and Kielce regions. The Łysogóry Region lies within the Łysogóry Block, whereas the Kielce Region is the northern part of a larger, tectonic block, called the Małopolska Block (e.g., Buła, 2000; Cocks and Torsvik, 2005). The Małopolska and Łysogóry blocks were situated close to the Baltica palaeocontinent (Cocks and Torsvik, 2005; Malinowski *et. al.*, 2005; Nawrocki and Poprawa, 2006). According to these authors, the Małopolska Block could have been a proximal terrane, although others have suggested an exotic origin for the unit (e.g., Belka *et al.*, 2000). The study area is situated in the southern and western parts of the Kielce Region.

The Czarna Shale Formation was the subject of several papers, which focussed mainly on its fossils and age (e.g., Żak, 1966; Orłowski, 1987, 1988, 1992a, 1997; Lendzion *et. al.*, 1982; Kowalski, 1983; Kowalczewski *et al.*, 1987, 2006; Kowalczewski, 1995, 1997). Żakowa and Jagielska (1970) described relatively few skeletal fossils from the Czarna Shale Formation recovered from the Bazów IG-1 borehole, including gastropods, hyoliths, crustaceans, in addition to algae and *incertae sedis*. The descriptions of the fossils in cores from this borehole were revised by Lendzion *et al.* (1982), who recognised inarticulate brachiopods, gastropods, hyoliths, crustaceans, trilobitoidea, acritarchs and trace fossils, including "*Granularia*", *Chondrites* isp. and unrecognised traces. Indeterminate Merostomoidea, algae and diversified acritarchs were described by Kowalski (1983). Orłowski and Waksmudzki (1986) described new species of hyoliths as skeletal fossils. Kowalczewski *et al.* (2006) mentioned foraminifers, molluscs, and bradoroid and anomalocarid arthropods as occurring in this formation.

Kowalski (1983, 1987) described some trace fossils from the Czarna Shale Formation, including *Agrichnium* isp., ?*Bunyerichnus* isp., *Didymaulichnus*, *Laevicyclus* isp., *Monomorphichnus* isp., *Neonereites* isp. (here included in *Nereites*), *Oldhamia antiqua* Kinahan, 1854, *Palaeophycus* isp., *Phycodes pedum* Seilacher, 1955 (here included in *Trichophycus pedum*), *Planolites annularis* Walcott, 1890, and *P. montanus* Richter, 1937 (in addition to *P. ballandus* Webby, 1970 and *P. nematus* Kowalski, 1987, which here are regarded as synonyms of *P. montanus*). Orłowski (1989) mentioned only *Diplocraterion parallelum* Torell, 1870, *Planolites beverleyensis* (Billings, 1862), *P. montanus* Richter, 1937 and specimens, described as *Scolicia* sp. (possibly representing *Didymaulichnus* isp. or *Teichichnus duplex* Schlirf and Bromley, 2007). The papers cited above contain systematic descriptions and data on the stratigraphic range of these trace fossils.

The purpose of this study is to describe new specimens of trace fossils from the Czarna Shale Formation, exposed in the vicinity of Kotuszów and observed in several cores in

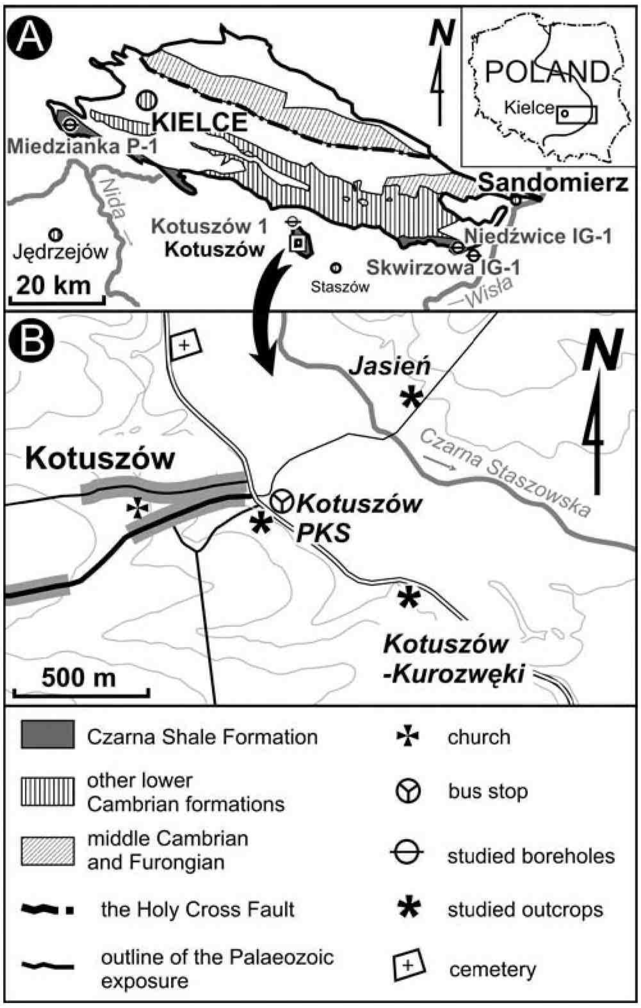

Fig. 1. Locality maps. **A** – Localities and simplified geological map of the Palaeozoic core of the Holy Cross Mountains (geology according to Orłowski, 1975; Mizerski *et al*., 1991 and Żylińska and Szczepanik, 2009; sketch after Stachacz, 2012, modified). **B** – Topographic map of the Kotuszów area, showing location of exposures

the southern and western parts of the Holy Cross Mountains, and to critically evaluate the taxonomy of selected ichnofossils. The ichnofabric index (*ii*), with reference to the scale provided by Droser and Bottjer (1986), and sedimentary structures, were also analysed. The specimens are housed in the Institute of Geological Sciences of the Jagiellonian University in Kraków. The material presented is a part of a Ph. D. thesis on the ichnology of the lower Cambrian in the Holy Cross Mountains (Stachacz, 2011).

EXPOSURES AND CORE DESCRIPTIONS

Three exposures, described below, and three borehole cores were analysed. The exposures are located near Kotuszów, on the banks of the Czarna Staszowska River (Fig. 1). The cores are housed in the archives of cores and geological samples of the Polish Geological Institute, National Research Institute (PGI), in Kielce. Three cores are from the south of the Holy Cross Mountains and one core comes from the western part of this region (Fig. 1). The Cambrian rocks from the Miedzianka P-1 borehole were described as the Czarna Shale Formation in the PGI archives. The cores, which have not been lithostratigraphically and biostratigraphically classified in the PGI archives, here are termed the ?Czarna Shale Formation and possibly represent undefined members of the formation. Furthermore, the Kotuszów IG-1 core contains silty-clayey, for the most part horizontally laminated shales of the Czarna Shale Formation, which also were examined. Unfortunately, this core is broken into small fragments and a detailed study of the structures and fossils is impossible.

Kotuszów PKS (GPS coordinates, WGS 84: N50°42’40.5’’; E021°10’01.9’’). The exposure is located in the right bank of the river in the centre of Kotuszów village, along the road and opposite the bus stop (Fig. 1B). Strongly weathered, clayey and silty shales, brownish in colour, are exposed. Isolated, thin to medium beds of siltstones occur within the clayey and silty shales. Indistinct hieroglyphs suggest a normal arrangement of the beds, which dip approximately 36°/42°. This rocks are referable to the Kotuszów Shale Member and make up the lower part of the Czarna Shale Formation (Orłowski, 1975; Kowalczewski *et al.*, 1987; Kowalczewski, 1995). Clayey and silty shales in this outcrop are for the most part horizontally laminated (Fig. 2A). They do not contain skeletal fossils; instead they yield fragments of algae, the trace fossil *Planolites* and rare bioturbation structures, in the form of mottles; ferruginous concretions of different shape have also been encountered.

Kotuszów-Kurozwęki (GPS coordinates, WGS 84: N50°36’15.4’’; E021°21’35.0’’). The exposure is a small pit in the escarpment, on the southern side of the Kotuszów-Kurozwęki road (Fig. 1B). A succession of thin- to medium-bedded (5–30 cm), hard siltstones, green in colour, with intercalations of grey, clayey shales and about 1 m thick, is exposed there. Mechanical hieroglyphs indicate that the arrangement of the beds is normal; the dip is approximately 43°/30°. These rocks were mistakenly referred by Kowalski (1983, 1987) to the Osiek Sandstone Formation (see also Kowalczewski, 1997). Generally, the beds are sharply defined and non-bioturbated; polished surfaces and thin sections reveal combined wave-current ripples in the siltstones, which resemble the small-scale, hummocky cross-stratification (Fig. 2B, C), typical of tempestites. However, some beds of siltstone contain rare and poorly preserved trace fossils, including *Planolites montanus,* unrecognised, possibly branched forms, and short, mechanical hieroglyphs on the soles of beds. Kowalski (1987) made reference to the trace fossil *Phycodes pedum* Seilacher, 1955 (here included in *Trichophycus pedum*) from this outcrop.

Jasień (GPS coordinates, WGS 84: N50°36’37.8’’; E021°04’53.3’’). This outcrop is 4 m high and located on the margin of a meadow on the left bank of the river, about 200 m to the north-east of the bridge across the river Czarna Staszowska, between the villages of Kotuszów and Jasień (Fig. 1B). Mainly silty and clayey shales, brownish on the weathered surfaces and olive-green on fresh fracture surfaces, are exposed. The arrangement of the beds is normal, on the basis of hieroglyphs, and the dip about 340°/20°. The

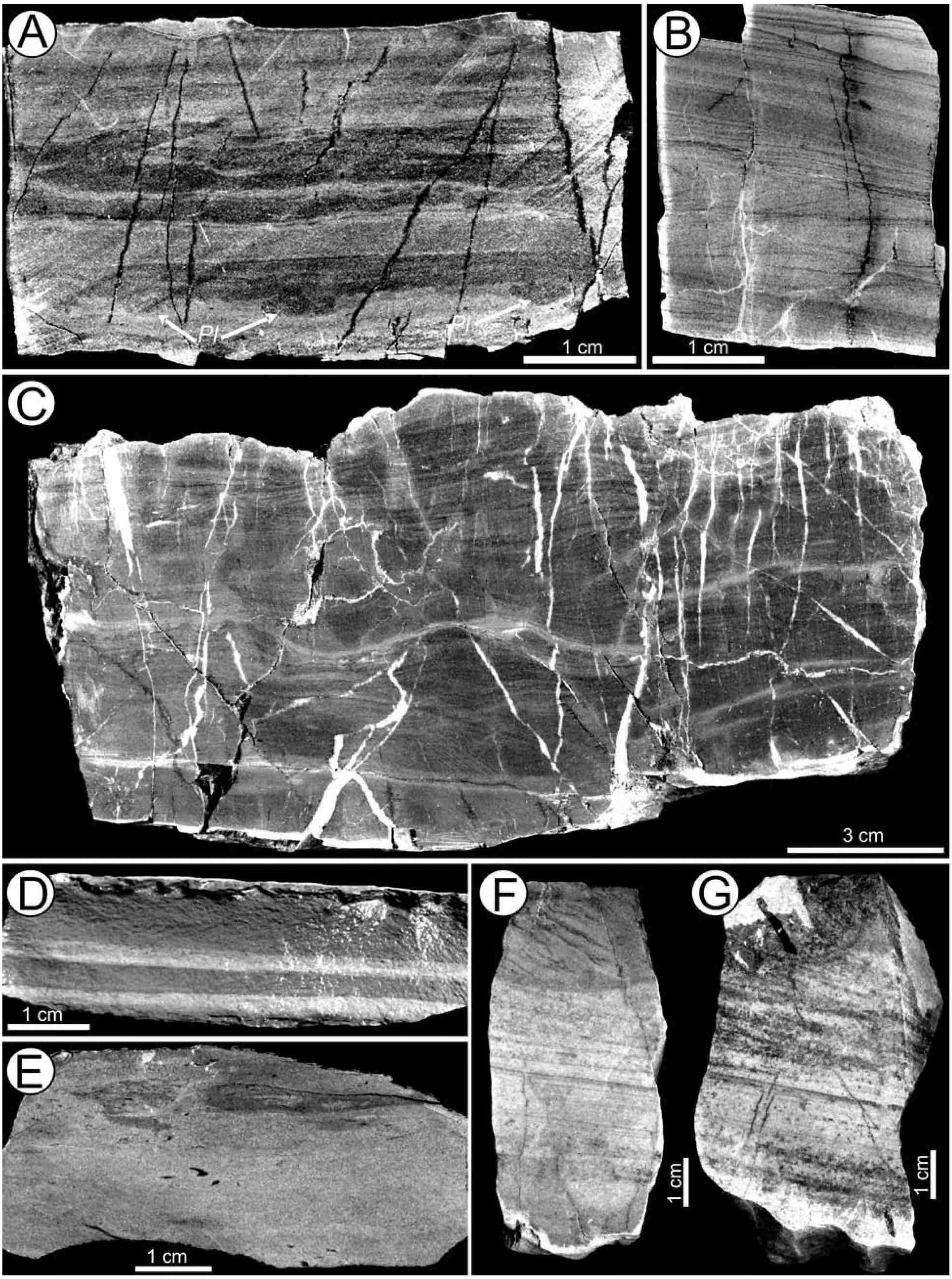

Fig. 2. Sedimentary structures from outcrops of Czarna Shale Formation. **A** – horizontally laminated siltstone with few specimens of *Planolites* (*Pl*), polished surface perpendicular to bedding, Kotuszów PKS exposure. **B, C** – non-bioturbated tempestite with wave-current ripples; A – thin section, B – polished surface of bed, both cut perpendicular to bedding, Kotuszów-Kurozwęki exposure. **D** – non-bioturbated (*ii* = 1), horizontally laminated claystone, side view of perpendicular to bedding fracture, core from Kotuszów IG-1 borehole. **E** – almost totally bioturbated (*ii* = 5) siltstone, polished surface perpendicular to bedding, Jasień exposure. **F, G** – low angle and riplle-cross-bedded sandstones, polished surfaces of beds, cut perpendicular to bedding

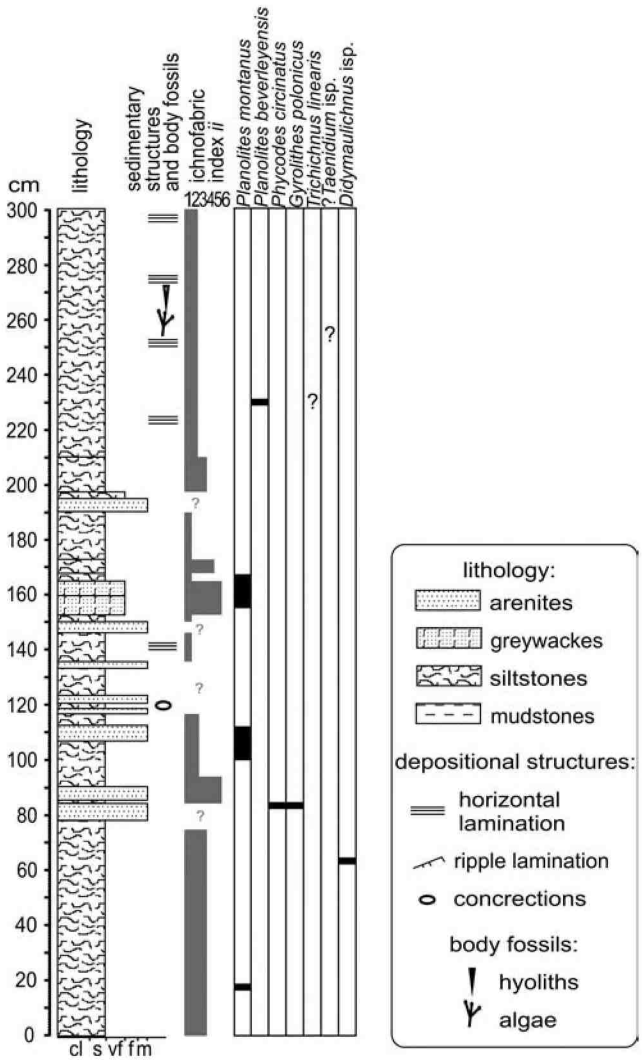

Fig. 3. Lithological column for Jasień exposure. Ichnofabric index *ii* according to Droser and Bottjer (1986). Explanations also applicable to Fig. 4

shales contain a few intercalated beds of sandstones, which are 420 cm thick. The shales also contain oval concretions and show a diversified level of bioturbation (ichnofabric index *ii* = 15, Fig. 2D, E). The sandstones are mostly horizontal- or cross-laminated (Fig. 2F, G), but in some places are without visible sedimentary structures. Skeletal fossils and trace fossils are rare and occur only in a few siltstone and sandstone beds. Poorly preserved hyoliths and fragments of algae were found here, in addition to seven ichnotaxa. described in the systematic part. The Jasień section and its ichnological data are shown in Fig. 3.

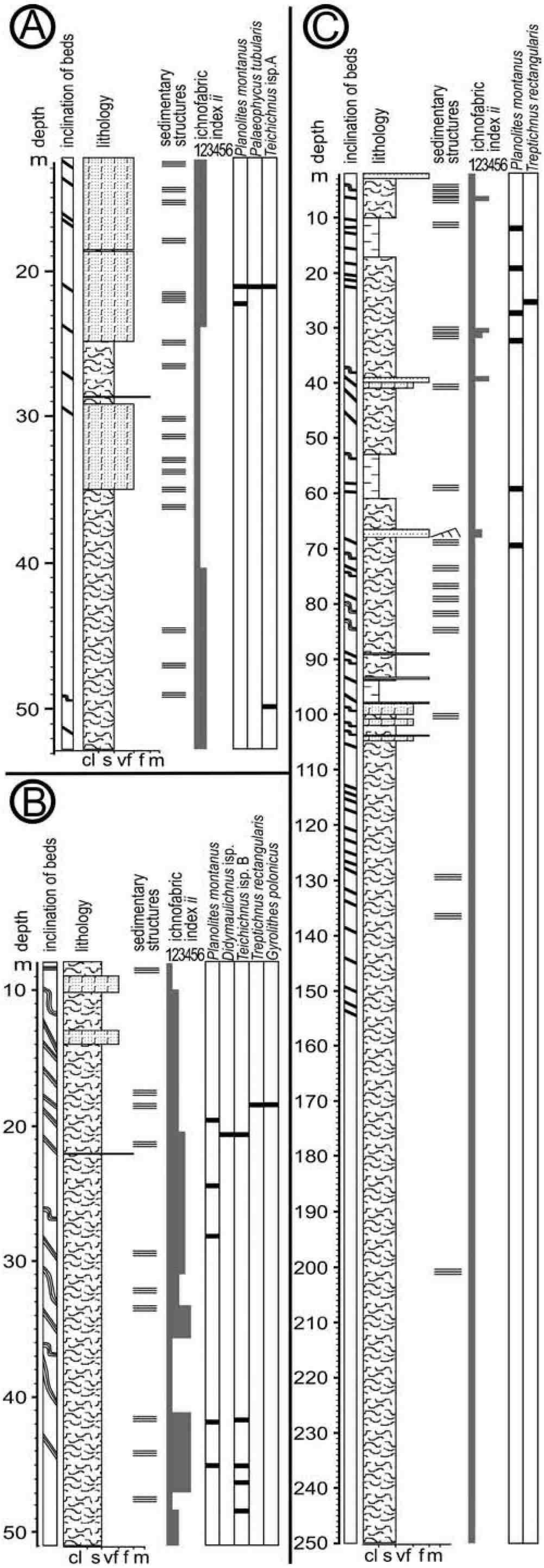

Fig. 4. Lithological columns of cores studied. **A** – Miedzianka P-1 borehole, **B** – Niedźwice IG-1 borehole, **C** – Skwirzowa IG-1 borehole. Ichnofabric index *ii* according to Droser and Bottjer (1986). Explanations as in Fig. 3

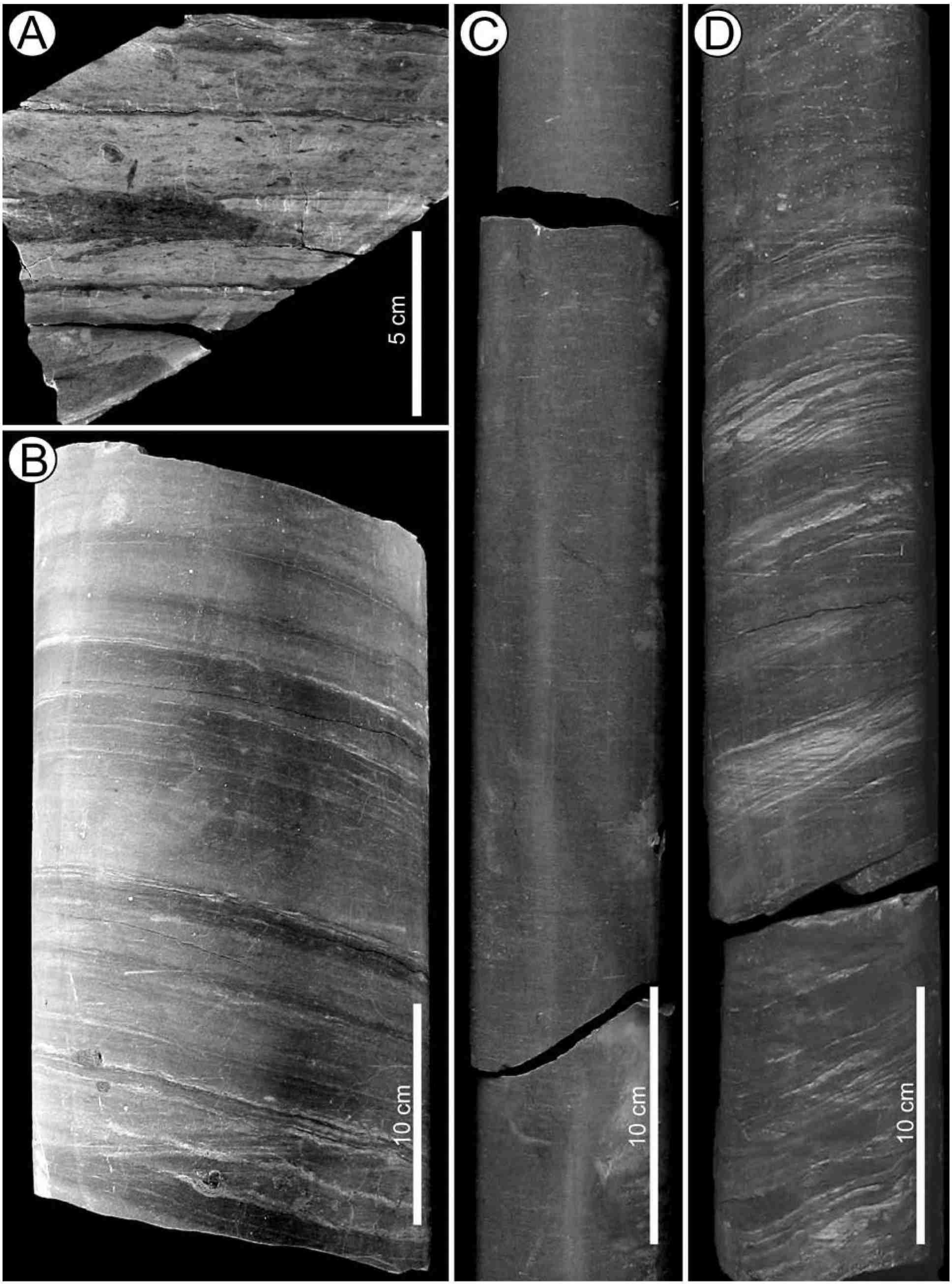

Fig. 5. Sedimentary structures in cores from ?Czarna Shale Formation. **A** – partly bioturbated (*ii* = 3–4) siltstone, polished surfaces perpendicular to bedding, core from Niedźwice IG–1 borehole. **B** – non-bioturbated, horizontally laminated siltstones, side view of fragment of core, Niedźwice IG–1 borehole. **C, D** – dark-grey and black, non-bioturbated siltstones, with thin layers of quartz arenite, side view of fragments of cores, Skwirzowa IG–1 borehole

The Miedzianka P-1 core (see Fig. 1A) contains the Czarna Shale Formation from 13 to 52.7 m in depth. The rocks form an isocline, with the beds inclined at 25–45° and folded in the lowermost part of the core. Heterolithic beds, composed of horizontal-laminated, grey siltstones, intercalated with 1–20 mm thick layers of quartz arenites, predominate. In the upper part of the core, approximately three thick series of greywackes and a one thin bed of quartz arenite occur. The siltstone is not bioturbated or only slightly bioturbated, and its ichnofabric index (*ii*) does not exceed 2. Trace fossils are rare, although a few ichnotaxa have been observed; they are described in the systematic part of this account. The lithological column of the Miedzianka P-1 borehole with the corresponding ichnological data are shown in Fig. 4A.

The Niedźwice IG-1 core (see Fig. 1A) contains the ?Czarna Shale Formation from 8 to 51 m in depth. The rocks form an isocline, although some parts of the core exhibit folding. Horizontally laminated, dark-olive and grey, poorly bioturbated siltstones predominate (Fig. 5A, B). In the upper part of the core, two 1-m thick series of grey- wackes and one bed of quartz arenite, a few cm thick, occur. Some parts of the core show more intense bioturbation (*ii* < 4). The lithologic section of the Niedźwice IG-1 borehole and related ichnological data are shown in Fig. 4B. A moderate number of trace fossils, containing a few ichnotaxa, were observed and are described in the systematic part.

The Skwirzowa IG-1 borehole (see Fig. 1A) contains the ?Czarna Shale Formation from 3 to 250 m in depth. The rocks are inclined at different angles and strongly folded in the greater part of the section. Dark-grey, black and brownish siltstones and silty-arenite heterolithic beds predominate (Fig. 5C, D). Less common are beds of greywackes, thin and localised beds of quartz arenites and clayey shales. The entire core is characterised by horizontal lamination with only one sandy bed, showing ripple cross-lamination. The sediment is mostly non-bioturbated (*ii* =1), except for a few horizons, where *ii* = 2–3. The trace fossils are rare and only a few specimens have been observed. The lithological section of the Skwirzowa IG-1 section and the corresponding ichnological data are shown in Fig. 4C.

OUTLINE OF LITHOSTRATIGRAPHY AND BIOSTRATIGRAPHY

The Cambrian Czarna Shale Formation of the Holy Cross Mountains consists mainly of siltstones, the thickness and age of which are poorly understood. According to Orłowski (1975, 1987, 1992a, b), Mizerski *et al.* (1986) and Orłowski and Mizerski (1995), its thickness exceeds 800 m. However, this value only refers to the part of the formation that is seen in exposures and cores. The lowermost part has never been drilled and therefore the thickness of the whole formation may be much greater (Kowalczewski *et al.*, 2006). Furthermore, the rocks of the Czarna Shale Formation are strongly folded and possibly tectonically repeated (Kowalczewski, 1997). The greater part of the Czarna Shale Formation does not contain body fossils and its age is unknown.

Traditionally, the Cambrian of the Holy Cross Group is subdivided into three series that are referred to the lower, middle and upper parts of the Cambrian (e.g., Orłowski, 1975). The threefold subdivision of the Cambrian is typical for the Baltica palaeocontinent (e.g., Babcock and Peng, 2007). According to the latest recommendations of the International Commission on Stratigraphy, the Cambrian is subdivided into four series, some of which are not yet named (e.g., Babcock *et. al.*, 2005; Babcock and Peng, 2007). Redefinition of the lower and middle Cambrian in the Holy Cross Mountains is complicated and definition of the lowermost Cambrian (Terreneuvian) may be impossible (Żylińska and Szczepanik, 2008). However, Żylińska and Szczepanik (2009) and Szczepanik (2010) adopted a fourfold subdivision of the Cambrian in the Holy Cross Mountains and assumed a possible Terreneuvian and Series 2 age for the Czarna Shale Formation.

Orłowski (1975, 1988, 1992a), Kowalski (1983, 1987) and Orłowski and Waksmudzki (1986) assumed a pre-*Holmia* (*Hyolithes-Allatheca* Zone) age of the upper part of the Czarna Shale Formation on the basis of discoveries of body fossils. It is noteworthy that trace fossils of arthropod (?trilobite) origin (*Monomorphichnus* isp., see Kowalski, 1987) occur only in the uppermost part of the Czarna Shale Formation. Possibly this is one of the reasons that the lower part of formation was considered by these authors to be referable to the pre-trilobitic Cambrian. According to Kowalczewski (1990, 1995), the entire Czarna Shale Formation represents the Lower Cambrian *Holmia* Zone. The presence of the genus *Skiagia* in acritarch assemblages indicates the *Holmia-Schmidtiellus* and *Protolenus-Issafeniella* zones for this formation in the Holy Cross Mountains (Pożaryski *et al.*, 1981; Kowalczewski *et al.*, 1987, 2006). Probably the formation represents a larger stratigraphic interval from the Terreneuvian up to the *Protolenus-Issafeniella* Zone (Kowalczewski *et al.*, 2006; Szczepanik and Żylińska, 2009; Szczepanik, 2010).

On the basis of the arrangement of beds and bibliographical data (Kowalczewski, 1995, 1997) believed that the Kotuszów PKS and Kotuszów-Kurozwęki exposures represent the lowermost, surface part of the formation, known as the Kotuszów Shale Member, whereas the Jasień exposure probably belongs to the top of the formation. The boreholes Miedzianka P-1, possibly both Niedźwice IG-1 and Skwirzowa IG-1, represent undetermined parts of the Czarna Shale Formation. Bibliographical data on the Czarna Shale Formation are insufficient and therefore a precise age of the formation remains unknown. In the present account, the entire Czarna Shale Formation is referred to possible the Terreneuvian and unnamed Series 2 parts of the Cambrian.

SYSTEMATIC DESCRIPTION

The trace fossils described in the present account were subdivided into morphogroups, as suggested by Książkiewicz (1977), including simple, branched, spreite and spiral structures.

Simple structures

Ichnogenus *Planolites* Nicholson, 1873

Diagnosis. Unlined, rarely branched, straight or tortuous, smooth surface, irregular or annulated, circular or elliptical in cross-section, of variable dimensions and configuration; homogeneous, structureless infillings of burrows, differing in lithology from the host rock (Pemberton and Frey, 1982; Stanley and Pickerill, 1998).

Remarks. *Planolites* Nicholson, 1873 is morphologically very similar to *Palaeophycus* Hall, 1847. Differences between them were for which delineated by Pemberton and Frey (1982), Fillion and Pickerill (1990) and Keighley and Pickerill (1995). *Planolites* is a very common structure, produced by worm-like deposit-feeders in all facies (e.g., Pemberton and Frey, 1982; Fillion and Pickerill, 1984).

Planolites montanus Richter, 1937
Fig. 6A

*1937 *Planolites montanus* sp. nov. – Richter, p. 151, figs. 1–5.
1970 *Planolites ballandus* sp. nov. – Webby, p. 95, fig. 14A–C.
1982 *Planolites montanus* Richter – Pemberton and Frey, p. 869, pls. 2.4, 7; 3.9; with the synonymy list.
1987 *Planolites nematus* isp. nov. – Kowalski, p. 25, pls. 2.1, 3; 5.3; 6.1–2.
1987 *Planolites ballandus* Webby, 1970 – Kowalski, p. 25, pls. 2.3, 3.1, 4; 4.1; 5.4; 6. 1, 3.
1987 *Planolites montanus* Richter – Kowalski, p. 25, pl. 4.1.
1989 *Planolites montanus* Richter, 1937 – Orłowski, p. 216, pl. 13.1–2.
1989 *Planolites ballandus* Webby, 1970 – Walter *et al.*, p. 235, fig. 10D, F.
1999 *Planolites montanus* Richter, 1937 – Mizerski *et al.*, p. 354, pl. 1.5a.
1999 *Planolites montanus* – MacNaughton and Narbonne, p. 108, fig. 7A.
2006 *Planolites montanus* Richter, 1937 – Gámez Vintaned *et al.*, p. 462, fig. 10.3a–b.

Material. Numerous specimens observed in the field, specimens in the cores of the Niedźwice IG-1 borehole.

Diagnosis. Relatively small, curved to contorted *Planolites*, less than 5 mm in diameter (Pemberton and Frey, 1982; Fillion and Pickerill, 1990).

Description. Specimens preserved as hypichnial semi-relief ridges or full-relief, elongate cylinders, which are straight or slightly curved, circular or elliptical in cross-section, oblate in the vertical axis. The surface of ridges or cylinders is smooth. They are 1–5 mm wide, unchanged in the whole length, which is up to 20 mm.

Remarks. Some of the small specimens are difficult to distinguish from small specimens of *Palaeophycus tubularis* Hall, 1847 (see Pemberton and Frey, 1982).

Occurrence. Cambrian, Czarna Shale Formation: Chęciny, Ołowianka hill, borehole 2 (Kowalski, 1987), Kotuszów, Jasień, Kotuszów-Kurozwęki, ?borehole Niedźwice IG-1.

Planolites beverleyensis (Billings, 1862)
Fig. 6B

1982 *Planolites beverleyensis* (Billings, 1862) – Pemberton and Frey, p. 866, pls. 1.7; 2.5, 8, 9; 5.8, 9; 3.1, 2, 7, 8; 5.1, 2; with the synonymy list.
1989 *Planolites beverleyensis* (Billings, 1862) – Orłowski, p. 216, pl. 13.3, 4.
1989 *Planolites beverleyensis* (Billings, 1862) – Walter *et al.*, p. 61, pls. 15.2–6, 16.1–6.
1996 *Planolites beverleyensis* (Billings, 1862) – Paczeşna, p. 235, fig. 10E, I.
1999 *Planolites beverleyensis* (Billings, 1862) – Mizerski *et. al.*, p. 354, pl. 1.1a, 5a.

Material. Eight specimens (INGUJ214P/Js29–37), numerous specimens observed in the field.

Diagnosis. Relatively large, unlined, smooth, horizontal to undulant, straight to sinuous, cylindrical burrows. The filling typically differs in colour from the surrounding sediment (Frey and Bromley, 1985).

Description. Specimens are preserved as hypichnial, slightly curved ridges. The ridges are semi-circular or elliptical in cross-section, the surface is smooth. They are 5–10 mm wide, unchanged in the entire length, which reaches at least 60 mm.

Remarks. Some of the small specimens are difficult to distinguish from representatives of the ichnospecies *Palaeophycus tubularis* Hall, 1847 (see: Pemberton and Frey, 1982).

Occurrence. Cambrian, Czarna Shale Formation: Jasień.

Ichnogenus *Palaeophycus* Hall, 1847

Diagnosis. Essentially cylindrical, predominantly horizontal, straight, slightly curved or undulating, ornamented or smooth, branched or unbranched, lined burrow. Bifurcations irregular, without swellings. Filling typically massive, similar to the host rock (compiled after: Pemberton and Frey, 1982; Fillion and Pickerill, 1984, 1990; Keighley and Pickerill, 1995).

Remarks. *Palaeophycus* Hall, 1847 is morphologically very similar to *Planolites* Nicholson, 1873. Remarks on the differences between these ichnogenera are provided by Pemberton and Frey (1982), Fillion and Pickerill (1990) and Keighley and Pickerill (1995). *Palaeophycus* is interpreted as structures produced by deposit-feeders or predators, usually moving parallel to the sediment surface (e.g., Pemberton and Frey, 1982).

Palaeophycus tubularis Hall, 1847
Fig. 6C

*1847 *Palaeophycus tubularis* sp. nov. – Hall, p. 7, pl. 2, figs. 1–2, 4–5.
1982 *Palaeophycus tubularis* Hall, 1847 – Pemberton and Frey, p. 856, pls. 1.1, 2, 5, 6, 8, 10; 2.1; 3.3, 6; 4.5; with the synonymy list.
1985 *Palaeophycus tubularis* Hall, 1847 – Crimes and Anderson, p. 327, fig. 10.3.
1989 *Palaeophycus tubularis* Hall, 1847 – Orłowski, p. 217, fig. 2, pl. 14.2–3.
1990 *Palaeophycus tubularis* Hall, 1847 – Fillion and Pickerill, p. 45, pl. 11.3, 6–7.
1996 *Palaeophycus tubularis* Hall, 1847 – Orłowski and Żylińska, p. 392, fig. 4A–B.
1996 *Palaeophycus tubularis* Hall, 1847 – Paczeşna, p. 58, fig. 2, pl. 9.2.
1997 *Palaeophycus tubularis* Hall, 1847 – Jensen, p. 75, figs. 47A, C; 48A, C, D; 49.
2006 *Palaeophycus tubularis* Hall, 1847 – Gámez Vintaned *et al.*, p. 459, fig. 10: 5b.

Material. Three specimens observed in the core from the Miedzianka P-1 borehole.

Description. Specimens preserved as hypichnial ridges on siltstone beds. Ridges are slightly curved, branched, circular to oval in cross-section. Their surface is smooth and distinctly lined. The entire structure may be up to 70 mm long; individual branches are 25–40 mm long and 3–5 mm wide.

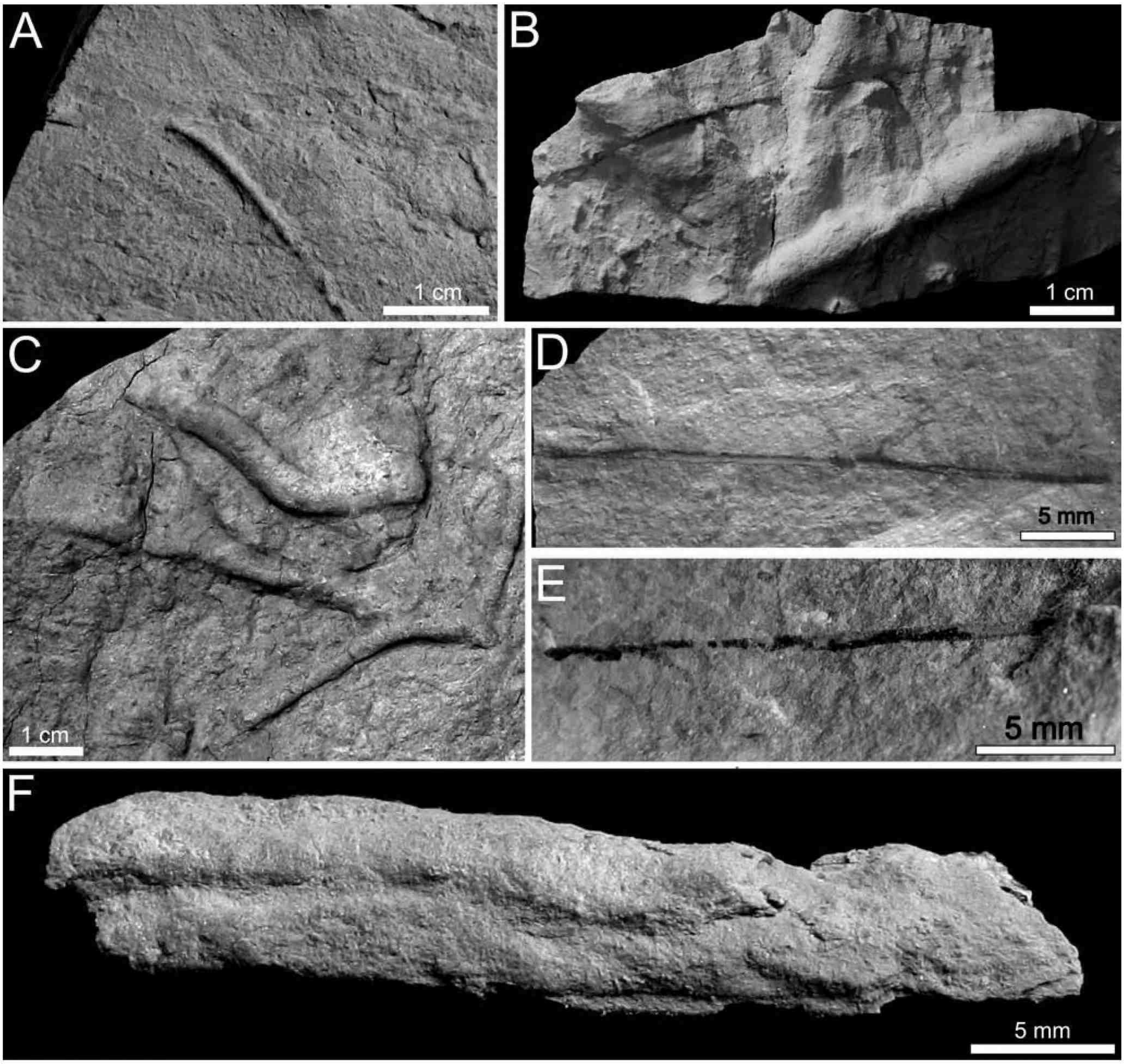

Fig. 6. Simple trace fossils from Czarna Shale Formation. **A** – *Planolites montanus* Richter, 1937, positive hyporelief on thin bed of siltstone; Niedźwice IG-1 borehole. **B** – *Planolites beverleyensis* (Billings, 1862), positive hyporelief on medium bed of quartz arenite, specimen coated with ammonium chloride, ING214P/Js37, Jasień. **C** – *Palaeophycus tubularis* Hall, 1847, positive hyporelief on medium bed of siltstone, Miedzianka P-1 borehole. **D, E** – *Trichichnus linearis* Frey, 1970, endichnia in thin beds of siltstone, INGUJ214P/Js5–6, Jasień. **F** – *Didymaulichnus* isp., positive hyporelief from thin bed of siltstone, Niedźwice IG-1 borehole

Remarks. The specimens discussed are very similar to the specimen of *P. tubularis* from the Cambrian Ociesęki Formation, illustrated by Orłowski (1989, fig. 2, pl. 14.2).
Occurrence. Cambrian, Czarna Shale Formation: Miedzianka P-1 borehole.

Ichnogenus *Trichichnus* Frey, 1970

Diagnosis. Branched or unbranched slender, threadlike, cylindrical, straight or sinuous burrow, less than 1 mm in diameter, oriented at various angles (mostly vertical) with respect to bedding. Burrow walls distinct or indistinct, lined or unlined (Frey, 1970; Fillion and Pickerill, 1990).

Remarks. The ichnogenus *Trichichnus* Frey, 1970 is interpreted as a domichnial structure of deposit-feeders (Frey, 1970) or a chemichnial structure, formed by chemosymbiontic organisms (Uchman 1995, 1999). *Trichichnus* is common both in shallow- and deep-marine environments (e.g., Wetzel, 1981). More details of the taxonomy and interpretation of this ichnogenus are provided by Fillion and Pickerill (1990) and Uchman (1995, 1999).

Trichichnus linearis Frey, 1970
Fig. 6D, E

*1970 *Trichichnus linearis* Frey, n. sp. – Frey, p. 20, fig. 4A, pl. 6.5–7.

1998 *Trichichnus linearis* Frey, 1970 – Uchman, p. 125, fig. 23.

Material. Two specimens (INGUJ214P/Js5–6).
Diagnosis. Lined *Trichichnus* (Frey, 1970).
Description. Specimens preserved as exichnial full relief, thread-like, walled cylinders in beds of siltstones. The cylinders are oriented at a low angle with respect to the bedding or horizontally. Diameter of cylinders is unchanging along the entire length, approximately 0.3 mm. Fragments of the specimens analysed are at least 20–40 mm long.
Remarks. The presence of distinct lining is a commonly accepted diagnostic feature of *T. linearis* Frey, 1970 (e.g., Frey, 1970, Uchman, 1998). However, Uchman (1999) postulated that the presence of lining is linked with diagenetic processes and should not be considered as diagnostic for this ichnospecies. The presence of *T. linearis* in the Cambrian Czarna Shale Formation extends the stratigraphic range of this ichnospecies, know so far only from the Ordovician (Fillion and Pickerill, 1990).
Occurrence. Cambrian, Czarna Shale Formation: Jasień.

Ichnogenus *Didymaulichnus* Young, 1972

Diagnosis. Straight or gently curved, moderately deep, smooth trail, which is bisected longitudinally by a narrow furrow, if preserved as hyporelief (Young, 1972; Fillion and Pickerill, 1990).
Remarks. *Didymaulichnus* Young, 1972 is morphologically similar to *Cruziana* d'Orbigny, 1842, but differs in the absence of ridges (moulds of scratch marks), perpendicular or oblique to the axis (Young, 1972). *Didymaulichnus* is interpreted as a locomotion trail of gastropods (Hakes, 1976) or trilobites (Crimes, 1970).

Didymaulichnus isp.
Fig. 6F

Material. One catalogued specimen (INGUJ214P/Js27) and one specimen, observed in the core of the Niedźwice IG-1 borehole.
Description. Positive hyporeliefs, preserved as slightly convex, gently curved bilobate ribbons. The ribbons are ellipsoidal in cross-section, their surface is smooth. In the median part of the ribbons, a distinct V-shaped, longitudinal furrow, about 1 mm deep, is present. The ribbon is at least 20–30 mm long and about 7 mm wide.
Remarks. The morphology of the trails analysed corresponds to the description of the ichnogenus *Didymaulichnus* Young, 1972. However, the state of preservation does not permit a more detailed determination.
Occurrence. Cambrian, Czarna Shale Formation: Jasień, ?Czarna Shale Formation: Niedźwice IG–1 borehole.

Branched structures

Ichnogenus *Phycodes* Richter, 1850

Diagnosis. Densely to loosely packed bundle of tunnels. These are joined as a single stem or tightly packed in the downward-directed, horizontal, proximal parts. The bundle is split and looser in the upward-penetrating, distal part (Uchman, 1998).
Remarks. The ichnogenus *Buthotrephis* Hall, 1852 has been recently included into *Phycodes* Richter, 1850 (e.g., Seilacher, 1955; Uchman, 1998). More details on the taxonomy of this ichnogenus and its interpretation were given e.g. by Seilacher (1955), Osgood (1970), Fillion and Pickerill (1990) and Uchman (1998). *Phycodes* was interpreted as a dwelling-feeding structure, produced by deposit-feeder organisms, during the penetration of nutrient-rich deposits (Seilacher, 1955; Osgood, 1970; Fillion and Pickerill, 1990).

Phycodes circinatus Richter, 1853
Fig. 7A

1990 *Phycodes circinatus* Richter, 1853 – Fillion and Pickerill, p. 46, pl. 11.4, 9, 10.
1999 *Phycodes palmatum* (Hall, 1852) – Mizerski *et al.*, p. 360, pl. 1.4.
2000 *Phycodes circinatum* Richter – Seilacher, p. 253, fig. 14; with the synonymy list.

Material. One specimen observed in the field, destroyed during preparation.
Diagnosis. Convex hyporelief, on the sole of a bed, composed of tightly packed bundles of retrusive spreite bodies that spread and curve back distally in a palmate fashion. Delicate, transverse corrugation can be present. The palmate, thin J- or U-shaped tubes are merged into the bed (slightly modified from Seilacher, 2000).
Description. Positive hyporelief, preserved as a short, horizontal cylinder, is subdivided into a bundle, composed of several smaller branches, radiating from the same point. The branches are similar in length. The entire structure is developed in a horizontal plane. Some of the branches are curved and J-shaped. Branches are circular or slightly oval in cross-section, their surfaces are smooth. The branches are 2–5 mm wide; the lengths of individual branches range between 30–70 mm.
Remarks. Very similar specimens have been described from the Ociesęki Sandstone Formation by Mizerski *et al.* (1999) as *Phycodes palmatus* Hall. However, *P. palmatus* differs from *P. circinatus* in the much larger diameter and looser density of the shafts (Fillion and Pickerill, 1990). The presence of *P. circinatus* in the Cambrian Czarna Shale Formation extends the stratigraphic range of this ichnospecies, so far only known from the Ordovician (Seilacher, 2000).
Occurrence. Cambrian, Czarna Shale Formation: Jasień.

Ichnogenus *Treptichnus* Miller, 1889

Diagnosis. Simple or zigzag-shaped, straight or curved complex of segments, associated with vertical or inclined tubes. The entire structures form a three-dimensional burrow system. Joined points of segments may exhibit small pits or short, twig-like projections (complied after Buatois and Mángano, 1993; Geyer and Uchman, 1995; Schlirf, 2000).
Remarks. *Treptichnus* Miller, 1889 is similar to *Trichophycus* Miller and Dyer, 1878. According to Schlirf (2000), *Treptichnus* consists only of a single tube, whereas *Trichophycus* is composed of a main tube, from which side tubes ramify. Problems with the taxonomy of *Treptichnus* and the similar *Trichophycus* and *Phycodes* have been discussed in numerous papers (e.g., Buatois and Mángano, 1993; Geyer and Uchman, 1995; Jensen, 1997 and Schlirf, 2000). *Treptichnus* is usually interpreted as fodinichnial or agrichnial structures, produced by worm-like organisms (e.g., Buatois and Mángano, 1993).

Treptichnus rectangularis Orłowski and Żylińska, 1996
Fig. 7B

*1996 *Treptichnus rectangularis* isp. nov. – Orłowski and Żylińska, p. 392, figs. 3D, 5, 6.
2002 *Treptichnus rectangularis* Orłowski and Żylińska, 1996 – Orłowski and Żylińska, p. 142, fig. 3g.
2008 *Treptichnus rectangularis* Orłowski and Żylińska, 1996 – Pacześna and Żylińska, p. 16, fig. 22.
2010 *Treptichnus rectangularis* Orłowski and Żylińska, 1996 – Vannier *et. al.*, p. 711, fig. 2B–E.

Material. One specimen (INGUJ214P/NIg1).
Diagnosis. Horizontal burrows, consisting of a system of short,

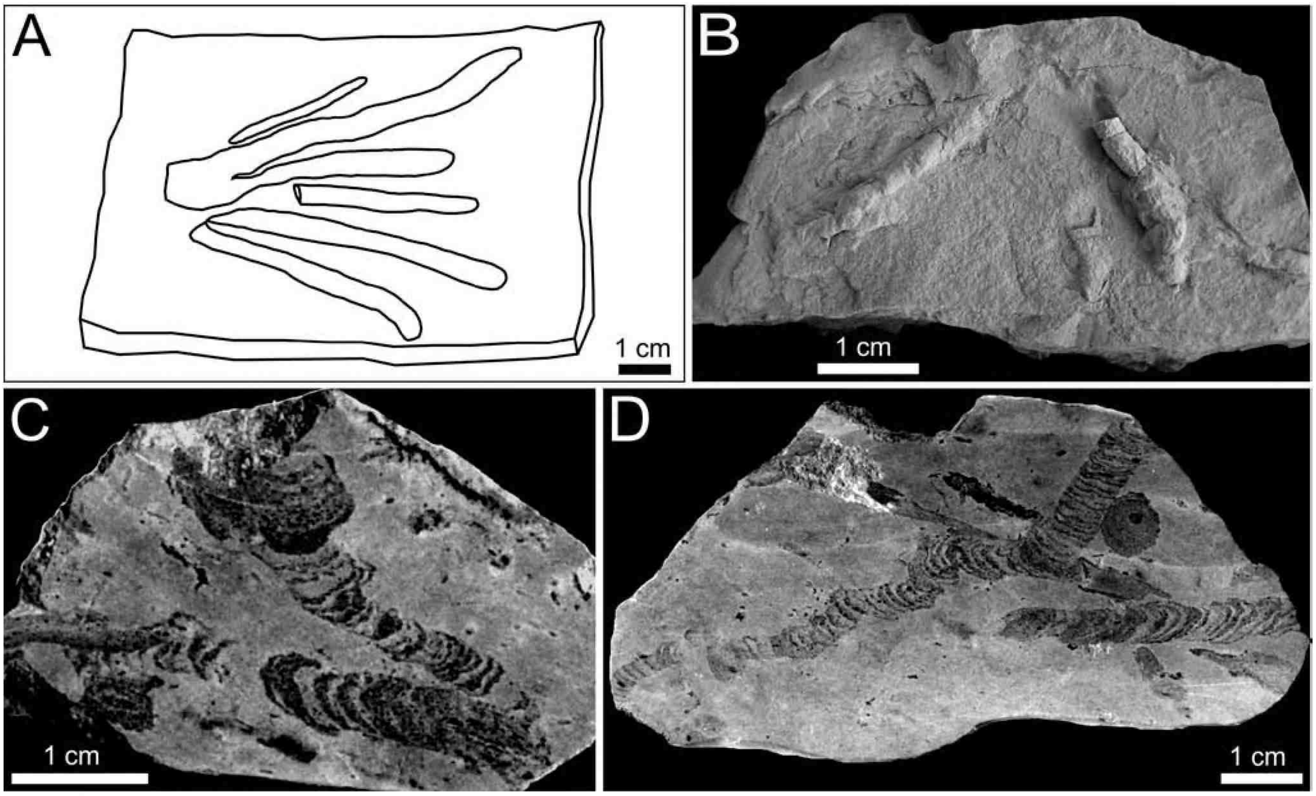

Fig. 7. Branched trace fossils from Czarna Shale Formation. **A** – *Phycodes circinatus* Richter, 1853, sketch of hypichnion on thin bed of siltstone from Jasień exposure. **B** – *Treptichnus rectangularis* Orłowski and Żylińska, 1996, endichnion in thin bed of siltstone, INGUJ214P/NIg1, Niedźwice IG-1 borehole. A, B – specimens coated with ammonium chloride. **C, D** – ?*Taenidium* isp., endichnia in thin beds of siltstone, view of polished surfaces, parallel to bedding, Jasień, INGUJ214P/Js2-3

tube-like units, emerging alternately, or on the same side from the periapertural part of the preceding unit, and opening vertically to the surface. Units are irregularly shaped and almost devoid of ornamentation, developed parallel to the bedding. The walls of burrows may be reinforced by faecal pellets (slightly modified from Orłowski and Żylińska, 1996).

Description. A zig-zag endichnion, composed of alternately arranged, horizontal cylinders. Individual cylinders are straight, indistinctly segmented, covered by delicate, longitudinal furrows. The segments are swollen at branching points. The cylinders are circular to oval in cross section; the angle between branches is about 60–90°. The entire structure is about 60 mm long; an individual branch is about 30 mm long and 3 mm wide.

Remarks. The specimen discussed here is similar to some specimens, representing *Trichophycus pedum* (Seilacher, 1955), but differs in the presence of swellings of the branching point. According to Dzik (2005) and Vannier *et al.* (2010), this ichnospecies was produced by priapulids or other worms, with locomotive behaviour, similar to that of Recent priapulids.

Occurrence. Cambrian, ?Czarna Shale Formation: Niedźwice IG-1 borehole.

Ichnogenus *Taenidium* Heer, 1877

Diagnosis. Variously oriented, unlined, straight, curved or sinuous, cylindrical trace fossil, containing a segmented fill, articulated by meniscus-shaped partings. Secondary branches may be present, but true branching is absent (D'Alessandro and Bromley, 1987; Keighley and Pickerill, 1994).

Remarks. *Taenidium* Heer, 1877 is a meniscate structure with a backfill, usually considered to be produced by an animal, progressing axially through the sediment and depositing alternating packets of differently constituted sediment behind it, as it moves forward (Bromley *et al.*, 1999). The taxonomy of this ichnogenus and similar ichnotaxa has been discussed by D'Alessandro and Bromley (1987) and Keighley and Pickerill (1994).

?*Taenidium* isp.
Fig. 7C, D

Material. Three specimens (INGUJ214P/Js1–3).

Description. Elongated, curved endichnia, composed of densely packed meniscate segments, the convexity of which is generally oriented towards one direction. In a cross-section of the whole structure, the meniscate segments are circular; in some places their margin is irregular. In longitudinal section, some segments are slightly undulated within the meniscate shape (Fig. 5D). Series of segments are differently oriented, but mostly spread along the horizontal plane. The preserved structures are 30–100 mm long and 4–6 mm wide. Thickness of individual segments 0.5–1 mm, distances between segments 0.51 mm.

Remarks. The specimens discussed are observed on polished surfaces in soft, silty shales. Cross-sections, made at various orientations, show different shapes of the meniscate segments. The specimens described may be a fragment of a larger trace fossil and the complete morphology of the whole structure is unknown. Fragments could be parts of e.g. *Zoophycos*. However, the state of preservation does not permit a more detailed determination. The three-dimensional appearance of the burrow suggests that the movement of the organism was not related to the sediment surface.

Occurrence. Cambrian, Czarna Shale Formation: Jasień.

Spreite structures

Ichnogenus *Teichichnus* Seilacher, 1955

Diagnosis. Long, straight, sinuous to zigzag-shaped, unbranched or branched, wall-like spreite structures, formed by vertical displacement of horizontal or oblique, erect to undulose tubes lacking wall-lining, resulting in single, gutter-shaped or double gutter-shaped spreite lamellae, as seen in transverse cross-section. Bioglyphs may be present (Schlirf and Bromley, 2007).
Remarks. *Teichichnus* was introduced by Seilacher (1955) for describing horizontal, dwelling-feeding structures, in the form of walls with parallel laminae, made by deposit-feeders, moving within the deposit.

Teichichnus isp. A
Fig. 8A, B

Material. One specimen (INGUJ214P/MP1) in the core from of the Miedzianka P-1 borehole.
Description. Full relief, elongate, unbranched, slightly winding endichnion in siltstone, filled with sand. The trace fossil is irregular in cross-section at one termination and close to a trapezium the other termination. The lower surface of the trace fossil is smooth and slightly convex. The upper surface is irregular, distinctly concave at one termination. Indistinct, flattened, U-shaped spreite are visible in the cross-section. The trace fossil is at least 40 mm long, 15 mm wide and 15 mm high.
Remarks. The specimen discussed differs from *T. rectus* Seilacher, 1955 in its angular, instead of U-shaped termination in cross-section.
Occurrence. Cambrian, Czarna Shale Formation, Miedzianka P-1 borehole.

Teichichnus isp. B
Fig. 8C

Material. One fragment of the core (INGUJ214P/Nd2) that contains two specimens and two further specimens, observed in the core from the Niedźwice IG-1 borehole.
Description. Endichnia preserved as full relief, elongate wedges in beds of siltstones, which are U-shaped or inverted, Ω -shaped in cross-section. The surface is smooth. The spreite are distinctly visible in cross-section. Specimen INGUJ214P/Nd2 (Fig. 6C) shows two series of spreite, laterally displaced, with regard to each other. The trace fossils are at least 30–100 mm long, 9–50 mm wide and 10–70 mm high.
Remarks. One of the illustrated specimens (INGUJ214P/Nd2; Fig. 6C) contains two laterally displaced series of spreite only. Therefore it is not clear whether the visible series represent two different specimens or fragments of a larger, branched structure. These specimens are similar to *Teichichnus zigzag* Frey and Bromley, 1985, but the occurrence of only small fragments of a possibly larger structure does not permit a more detailed determination.
Occurrence. Cambrian, ?Czarna Shale Formation: Niedźwice IG-1 borehole.

Ichnogenus *Dictyodora* Weiss, 1884

Diagnosis. Three-dimensional spreite burrow, roughly conical, vertical to the bedding; conical in vertical plane; very thin spreite with exterior surface indistinctly striated. The structures form meanders or spirals, visible on the bedding plane, which correspond to the intersection of the spreite wall with the bedding surface (compiled after Häntzschel, 1975; Benton, 1982a; Baucon and Neto de Carvalho, 2008).
Remarks. *Dictyodora* includes complicated structures, composed of a meandering, basal burrow and a dorsal, striated wall (e.g., Benton and Trewin, 1980). Some ichnospecies of this ichnogenus previously were described under different ichnogeneric names, including *Myrianites* for the vertical wall and *Crossopodia* for the basal burrow (Benton and Trewin, 1980; Benton, 1982a, b). *Dictyodora* is interpreted as meandering burrows and trails produced by worms or molluscs, efficiently utilising part of the sea bed as a food source (Benton and Trewin, 1980). This ichnogenus is known from Cambrian (e.g., Seilacher, 1955, 1967) to Carboniferous strata (e.g., Benton, 1982a; Baucon and Neto de Carvalho, 2008). More details on the taxonomy and ethology of *Dictyodora* have been provided by Seilacher (1955, 1967), Benton and Trewin (1980), and Benton (1982a, b).

?*Dictyodora* isp.
Fig. 8D–G

Material. Two specimens (INGUJ214P/Js21–22).
Description. Short fragments of endichnia, preserved as sandy infillings in a siltstone bed, composed of a basal burrow and a dorsal, vertical crest (wall *sensu* Benton and Trewin, 1980 and Benton, 1982a). The basal burrow is an elongated ribbon, gutter-shaped in cross-section, essentially filled with quartz arenite. It increases in width in one direction and resembles a wedge. The infilling of the basal burrow is homogeneous, in part indistinctly laminated. The dorsal crest, visible in the smaller specimen, is curved or undulated in cross-section. The basal burrow to vertical crest width ratio is about 5. The basal burrow is 9–15 mm wide and 5–7 mm high in the smaller specimen, and 2040 mm wide and 2030 mm high in the larger specimen. The smaller specimen is at least 40 mm long and the larger one is at least 70 mm long.
Remarks. The specimens described are preserved only as small fragments of most probably much larger structures, but they display features, characteristic of *Dictyodora*. However, the state of preservation does not permit a more detailed determination.
Occurrence. Cambrian, Czarna Shale Formation: Jasień.

Spiral structures

Ichnogenus *Gyrolithes* Saporta, 1884

Diagnosis. Rarely branched, spiral burrows; helix essentially vertical, consisting of dextral, sinistral or reversing coils, which are not in contact (Bromley and Frey, 1974, Uchman and Hanken, 2012).
Remarks. *Spiroscolex* Torell, 1870 is regarded as an older synonym of *Gyrolithes* Saporta, 1884 (e.g., Jensen, 1997). Details of the taxonomy of *Gyrolithes* and similar ichnotaxa are provided by e.g., Bromley and Frey (1974) and Jensen (1997). *Gyrolithes* is interpreted as a dwelling-feeding structure, possibly a connection between the sediment surface and the nutrient-containing layer (Jensen, 1997). The morphometric parameters, based on burrow width to whorl radius ratio, have been proposed by Uchman and Hanken (2012) as diagnostic features, among others. The oldest ichnospecies of *Gyrolithes* are known from the Cambrian–Lower Ordovician strata, but younger ichnospecies have been described from Permian–Miocene strata (Uchman and Hanken, 2012).

Gyrolithes polonicus Fedonkin, 1981
Fig. 9A–C

*1981 *Gyrolithes polonicus* Fedonkin sp. nov. – Fedonkin, p. 80, pl. 22.1–5, 8.
1985 *Gyrolithes polonicus* Fedonkin, 1981 – Crimes and Anderson, p. 32, fig. 6.7–8.

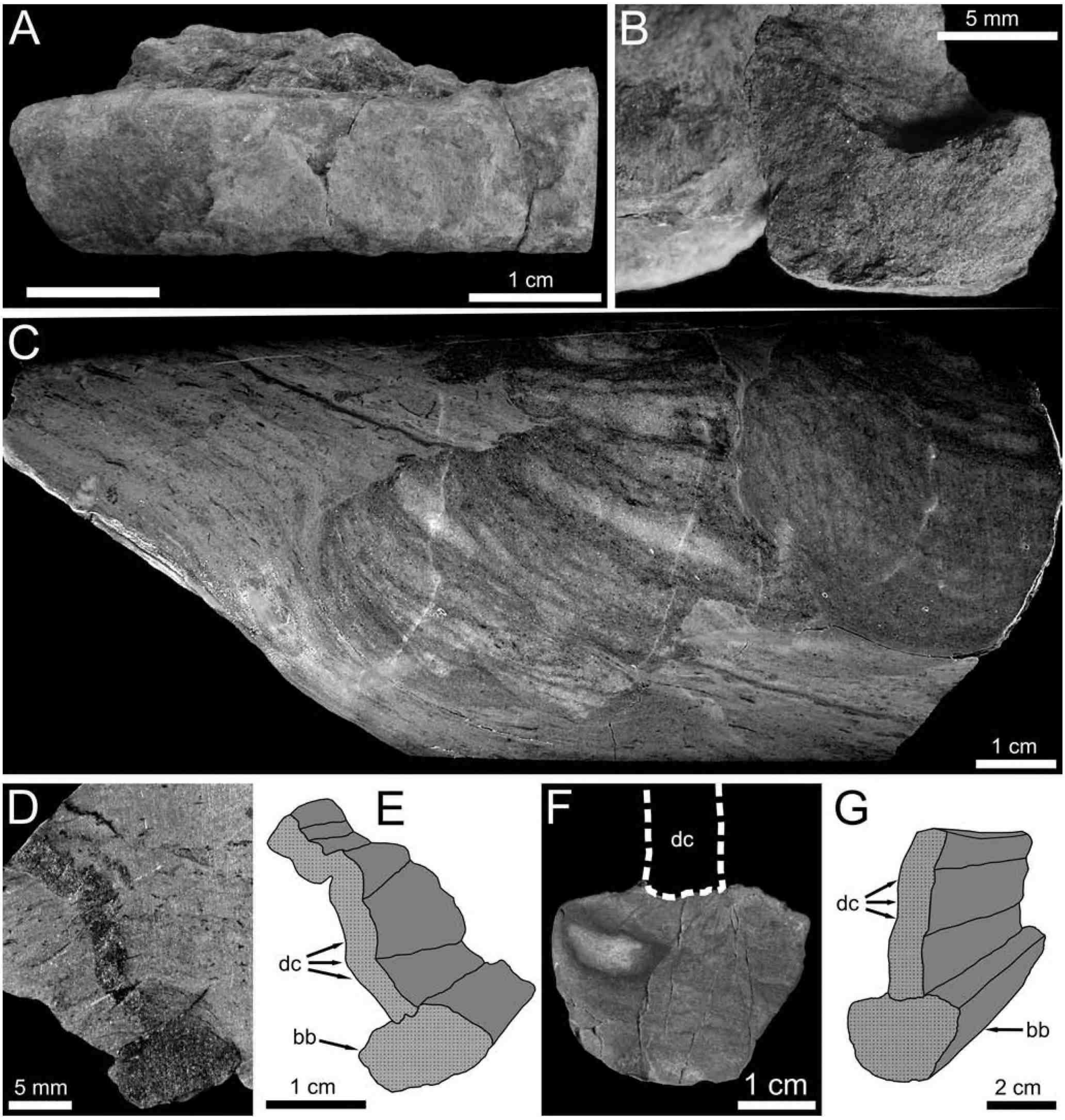

Fig. 8. Spreite trace fossils from Czarna Shale Formation. **A, B** – *Teichichnus* isp. A, positive hypichnion on thin bed of siltstone, INGUJ214P/MP1, A – view from the bed sole, specimen arrowed, B – side view of fractured specimen, Miedzianka P-1 borehole. **C** – *Teichichnus* isp. B, view of polished and oiled fragment of core, INGUJ214P/Nd2, Niedźwice IG-1 borehole. **D–G** – ?*Dictyodora* isp., endichnia in thin beds of siltstone, Jasień, INGUJ214P/Js21-22. D, F – cross-sections, F – specimens with sketch of part of reconstructed wall, E, G – 3D reconstruction of fragments of specimens INGUJ214P/Js21–22; bb – basal burrow, dc – dorsal crest

1997 *Gyrolithes polonicus* Fedonkin, 1981 – Jensen, p. 51, figs. 30, 34, 35, 36C–D, 64A–B; with the synonymy list.

2012 *Gyrolithes polonicus* Fedonkin, 1981 – Uchman and Hanken (2012).

Material. One catalogued specimen (INGUJ214P/Js8) and one specimen, observed in the core from the Niedźwice IG-1 borehole.

Diagnosis. *Gyrolithes* with local, perpendicular striations. Burrow is 1–15 mm wide, radius of whorls is 1–19 mm. Usually only a few whorls are present (emended diagnosis of Uchman and Hanken, 2012).

Description. The trace fossils analysed are represented by two different specimens. The first specimen is preserved as an exichnion siltstone, filled with sandy sediment, forming a single, spiral burrow, with its axis perpendicular to the bedding surfaces. The spiral is short, tightly corkscrew-like and coiled, with an indistinct wall. The whorl radius is 4 mm, the burrow is about 5 mm wide. The

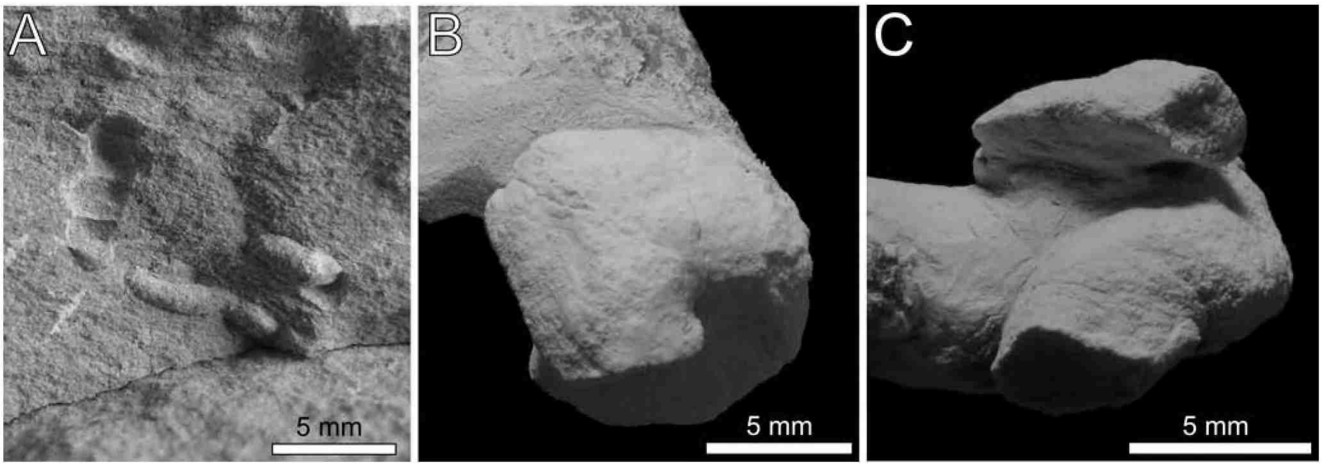

Fig. 9. Spiral trace fossils from Czarna Shale Formation. **A–C** – *Gyrolithes polonicus* Fedonkin, 1981, exichnia in thin beds of siltstone. A – Niedźwice IG-1 borehole, side view; B, C – INGUJ214P/Js8, specimen coated with ammonium chloride, Jasień; B – top-view, C – side-view

second specimen is preserved in the form of double, connected spirals, with the axis perpendicular to the bedding surface. In the latter case, the spirals are connected in their lower part by partly erected and elongated, distinctly walled whorls. The whorl radius is 2 mm, the burrow is 1.5 mm wide. The distance between the connected spirals is 5 mm.

Remarks. The two different specimens are assigned here to *G. polonicus* Fedonkin, 1981. Similar specimens, composed of two or more spirals, described as *G. polonicus* Fedonkin, 1981, are known e.g. from the Cambrian of Sweden (Jensen, 1997). *G. polonicus* occurs mostly in the Cambrian. However, single specimens have also been noted in the Lower Ordovician (Uchman and Hanken, 2012). The diagnosis for *G. polonicus*, proposed by Uchman and Hanken (2012), is emended herein, because the authors suggest a minimal radius for the whorl of this ichnospecies as 3.5 mm, whereas the dimension of the specimens described here is only 2 mm. Similar morphometric parameters are revealed in the small *G. lorcaensis* Uchman and Hanken, 2012 from the Miocene of Spain, which differs from the ichnospecies analysed in the absence of a wall (Uchman and Hanken, 2012).

Occurrence. Cambrian, Czarna Shale Formation: Jasień. ?Czarna Shale Formation, Niedźwice IG-1 borehole.

DISCUSSION

Strata of the Czarna Shale Formation are characterised by a low degree of bioturbation in all the localities and cores fragments studied. Trace fossils are generally rare and their diversity is low, with the prevalence of horizontal feeding-structures, typical of the *Cruziana* ichnofacies *sensu* Seilacher (1967) (Kowalski, 1987) or, more precisely, the distal *Cruziana* ichnofacies (see Pemberton *et. al.*, 2001).

Only ten ichnogenera and twelve ichnospecies are described here from the Czarna Shale Formation, whereas fifty ichnogenera and over eighty ichnospecies are known from the entire Cambrian of the Holy Cross Mountains (based on Kowalski, 1983, 1987; Orłowski, 1989, 1992b; Orłowski and Żylińska, 2002; Stachacz, 2011, 2012). Most of the known Cambrian trace fossils of the Holy Cross Mountains come from the Ociesęki Sandstone Formation (e.g., Orłowski and Żylińska, 2002). High ichnotaxonomical diversification within the sandstones of the Ociesęki Sandstone Formation units reflects favourable, environmental conditions for the benthic fauna, during deposition of the sands. Environments, dominated by silt and mud deposition, i.e. these of the Czarna Shale Formation and Kamieniec Shale Formation, are characterised by assemblages of trace fossils with low diversification (Orłowski and Żylińska, 2002). However, *Phycodes circinatus*, ?*Taenidium* isp., *Trichichnus linearis* and ?*Dictyodora* isp. of the Czarna Shale Formation are described for the first time from the Cambrian of the Holy Cross Mountains. The presence of *Trichichnus linearis* and *P. circinatus* in the Cambrian Czarna Shale Formation extends the stratigraphic ranges of these ichnospecies, know so far only from the Ordovician (see: Fillion and Pickerill, 1990; Seilacher, 2000).

According to Kowalski (1987) and the observations made during this study, the abundance of both body and trace fossils increases towards the top of the Czarna Shale Formation and trace fossils of arthropod (?trilobites) origin appear in its uppermost part. Smaller numbers of trace fossils and their low diversity in the silty facies, as in the case of the Czarna Shale Formation, resulted from a deeper environment of deposition and possibly from periodic anoxia of the seabed, as suggested by the dark colour of the sediment.

Kowalski (1987) proposed a littoral, low-energy environment of deposition, with maximum depth of 30 m for the Czarna Shale Formation. According to Kowalczewski *et al.* (2006), the silty-clayey sediments of the Czarna Shale Formation were deposited on a siliciclastic shelf, but did not provide a depth for the basin of deposition. Orłowski (1989) mentioned possible deposition of these sediments in deeper environments, referable to the *Nereites* ichnofacies. Malec (1996) even postulated a deep-water, turbiditic environment for the Czarna Shale Formation. However, there are no Bouma sequences, typical of turbidites (see Einsele and Seilacher, 1991; Monaco, 1996).

The sedimentological and ichnological features described here suggest deposition of the Czarna Shale Formation in the lower and upper offshore. This setting is confirmed by clayey-silt-dominated deposits, incorporating rare, isolated beds with combined wave-current ripples, resembling small- scale hummocky cross-stratification and horizontal, ripple and low-angle cross-laminated sandstones and siltstones, interpreted here as distal tempestites (see Einsele and Seilacher, 1991; Monaco, 1996). Such sedimentary structures, together with the trace fossil assemblages, are similar to the offshore, siliciclastic deposits in the Cretaceous of North America, interpreted by Pemberton *et al.* (2001). The preservation of thin, distal tempestites was possible, because the offshore, silty deposits were less intensively bioturbated, by comparison with the Mesozoic basins (Pemberton *et al.*, 2001). The number of tempestites increases toward the top of the formation in the stratotype area (Kotuszów and Jasień), which is taken to indicate a shallowing of the basin (Kowalczewski *et. al.*, 1987).

CONCLUSIONS

The Czarna Shale Formation is dominated by non-bioturbated and slightly bioturbated clayey-siltstones that contain rare silty and sandy tempestites

Trace fossils, occurring in isolated beds, are uncommon and poorly diversified.

Twelve ichnotaxa in ten ichnogenera are recognised; four ichnospecies and four ichnotaxa in open nomenclature from the Czarna Shale Formation are described for the first time.

Four ichnotaxa: *Phycodes circinatus*, ?*Taenidium* isp., *Trichichnus linearis* and ?*Dictyodora* isp. are described from the Cambrian of the Holy Cross Mountains for the first time.

The stratigraphic ranges of *Trichichnus linearis* and *Phycodes circinatus,* previously known only from the Ordovician and younger strata, have been extended.

The Czarna Shale Formation was deposited in the upper and lower offshore, in close proximity to the storm wave base. There may have been periodic anoxia on the seafloor.

Acknowledgments

I would like to thank Alfred Uchman (Institute of Geological Sciences, Jagiellonian University in Kraków) for his help during the preparation of the manuscript. Stanisław Orłowski (Institute of Geology, University of Warsaw) is acknowledged for discussion and access to his collection of trace fossils for study. I am grateful to Stanisław Leszczyński (Institute of Geological Sciences, Jagiellonian University in Kraków) for discussions of sedimentary structures. I wish to thank Anna Żylińska (Institute of Geology, University of Warsaw) and Sören Jensen (Area de Paleontologia, Facultad de Ciencias, Universidad de Extremadura, Badajoz, Spain) for their comments on an earlier version of this paper. The research was supported by the Polish Ministry of Science and Higher Education (grant no. NN 307 102935).

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